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A Review on Heavy Metal Absorption Capacity of Aquatic Plants: Sources, Impact and Remediation Technique

Krupa Unadkat and Punita Parikh
Department of Botany, Faculty of Science,
The Maharaja Sayajirao, University of Baroda, Vadodara, Gujrat, India.

Abstract - Increasing urbanization, industrialization, over population and habitat modification are leading causes of environmental deprivation and pollution. Heavy metals such as Zn, Cd, Ni, Pb, as etc. are one of the most toxic pollutants which show hazardous effects on all living things. The prevailing purification technologies used for removal of contaminants from wastewater are not only very costly but causes negative impact on ecosystem subsequently. Phytoremediation, an eco-friendly technology which is both ecologically sound and economically feasible is an attractive alternative to the current cleanup methods that are very expensive. This technology involves efficient use of plants including aquatic plants to detoxify or immobilize heavy metals. Aquatic plants are already being used in waste water treatment since long. Thus, this paper reviews the current state of phytoremediation technique based on aquatic plants as an innovative technology and to discuss its usefulness and potential in the waste water remediation.3

Keywords: Phytoremediation, Waste water, Aquatic plants, Heavy metals, Toxic pollutants.

I. Introduction

Aquatic ecosystems (habitats and organisms) include our rivers and streams, ponds and lakes, oceans and bays, and swamps and marshes, and their associated animals. These species have evolved and adapted to watery habitats over millions of years. Aquatic habitats provide the food, water, shelter, and space essential for the survival of aquatic animals and plants. The greater the diversity of habitats, whether in water or on land, the greater the biodiversity will be. Coastal estuaries and mangrove swamps, for example, are “edge” ecosystems that link salt- and freshwaters and trap nutrients that allow them to support a rich diversity of aquatic plants and animals. Sustaining aquatic biodiversity is essential to the health of our environment and to the quality of human life. We depend on many aquatic plants and animals, and their ecological functions, for our survival. For example, we use surface waters and their inhabitants to help process our waste products. Each day, aquatic organisms (bacteria and fungi) continuously break down harmful toxins and nutrients that we flush into our sewage systems or discard directly into our rivers and streams.

Aquatic and terrestrial biodiversity are sources of medicine, food, energy, shelter, and the raw materials that we use and need. Although we seldom recognize them, each aquatic species has an important role in making our lives easier, healthier, and more productive. Every living organism has an important role to play, and many are indispensable (Paul *et al*., 2015).

Human activities cause species to disappear at an alarming rate. Aquatic species are at a higher risk of extinction than mammals and birds. Losses of this magnitude impact the entire ecosystem, depriving valuable resources used to provide food, medicines, and industrial materials to human beings. Runoff from agricultural and urban areas, the invasion of exotic species, and the creation of dams and water diversion have been identified as the greatest challenges to freshwater environments (Allan and Flecker, 1993). Other threats to aquatic biodiversity include urban development and resource-based industries, such as mining and forestry that destroy or reduce natural habitats. In addition, air and water pollution, sedimentation and erosion, and climate change also pose threats to aquatic biodiversity. Water contamination by heavy metals in some area is practically unavoidable owing to natural process (weathering of rocks) and anthropogenic activities (industrial, agricultural and domestic effluents) (Sugiyama, 1994). Environmental exposure to toxic heavy metals is one of the main important issues on environment and public health (Kanoun-Boule et al., 2009).

II. Sources of Heavy Metals

Excess heavy metals in the soil and water originate from various sources, which include atmospheric deposition, sewage irrigation, improper stacking of the industrial solid waste, mining activities, the use of pesticides and fertilizers.

Natural sources

In nature excessive levels of trace metals may occur by geographical phenomena like volcanic eruptions, weathering of rocks, leaching into rivers, lakes and oceans due to action of water.

Agricultural Sources

Application of chemical fertilizers, animal manure, pesticides, waster water irrigation and pesticides are main agricultural sources responsible for heavy metal pollution.

Industrial sources

Small amounts of heavy metals are released while mining and uncontrolled smelting of large quantities of metal, ores in open fires. With the industrial revolution, metals were extracted from natural resources and processed in the industries from where heavy metals passed in to the atmosphere.

III. Impact of Heavy Metals on Aquatic Plants

Low concentration of heavy metals will not affect the growth of the plants in a certain range. But if the concentration is too high, the content of heavy metals enriched by the plant exceeds its tolerance threshold, and thus the plant will be poisoned and it even leads to death of the plant. Vascular aquatic macrophytes may accumulate considerable amounts of heavy metals in their tissues (Kovacks *et al*., 1984). In the recent past, several of the submerged, emergent and free floating aquatic macrophytes are reported to bioconcentrate heavy metals in natural waters as well as after exposure to wastewaters (Greger, 1999).Some aquatic or semi aquatic plants such as *Eichornia crassipes* (Dierberg *et al*., 1987), Nasturtium *officinale* and *Mentha aquatica* (Saygıdeger, 2005) can take up heavy metals from contaminated solutions. Metal accumulation in the form of Ca- oxalate crystals found on the aquatic plant *Echhornia Crassipes* (Mazen and Maghraby, 1997). It has been found that highest bioaccumulation is seen with zinc, copper, iron and nickel, which are found in the *Typha latifolia* rhizome. Furthermore, it has been found that concentration of cadmium is highest in the stalk, while lead and manganese are found to accumulate mostly in leaves of *Typha latifolia*. It is characteristic that there is no nickel in leaves, and that accumulations of zinc, iron and manganese are lowest in plant stalk.

IV. Impact of Heavy Metals on Humans

Heavy metal affects the urban environmental quality and damage human health indirectly through polluting the food, water and atmosphere. The higher concentration of chemicals in environment, the more children with inconsistent physiological reaction were found. Children living in polluted areas more often had hypertrophy of tonsils, increased lymphatic nodes and liver size and dimorphic features. Children dwelling in environmentally unfavorable areas showed significant decrease in immunity. Negative influence of toxicants took the form of secondary immune-deficiency state, which was expressed by repeated respiratory infections, etc. Due to the accumulation of heavy metals in humans, effective rehabilitation treatment, which includes pectin-vitamin tablets, natural adaptogenes and antioxidants, have been tested and proposed.

At least 23 metals have been classified as heavy metals the most common lead(Pb), Cadmium (Cd), Cobalt (Co), Chromium (Cr) Mercury (Hg), which have the toxic effects of high concentration as well as low concentration of plants (Abbas et al., 2015).

V. Conventional Methods for Removal

The conventional methods used for reduction in the concentration of heavy metal from the contaminated environment are listed in table no. 1.

Table 1: Conventional methods for removal of heavy metals

Methods	Mechanism	Advantages	Disadvantages
Reverse Osmosis	Separated by a semipermiable membrane at a pressure greater than osmotic pressure caused by the dissolved solids in waste water.	The ability to reduce the concentration of other ionic contaminants as well as dissolved organic compounds.	Cogging of membrane and expensive.

Ion Exchange	Metal ions form dilute solutions are exchanged with ions held by electrostatic forces in the exchange resin. Ion exchange uses mainly hydrocarbon derived polymeric resins.	Effective removal of dissolved heavy metal in the acidic pH range.	High cost and partial removal of certain ions.
Chemical Precipitation	Precipitation of metals is achieved by the addition of coagulants such as alum, lime, iron salts and other organic polymers.	It can be justified by their low costs and can be performed by a simple pH adjustment.	The large amount of sludge containing toxic compounds produced.
Electrodialysis	The ionic components (Heavy metals) are separated through the use of semipermeable on selective membranes. Application of an electrical potential between the two electrodes causes a migration of cations and anions towards respective electrodes.	Osmotic pressure is not a factor in ED system, so the pressure can be used for concentrating salt solutions to 20% higher.	The formation of metal hydroxides, which clog the membrane.

Source: Akpor and Muchie (2010); Singh et al., (2012)

VI. Reports of some Aquatic Macrophyte as Heavy Metal Accumulator

The Conventional methods presently in existence for removal of heavy metals from contaminated water include reverse osmosis, Ion Exchange, Chemical precipitation and electrolysis. These methods have many disadvantages.

Bioremoval of heavy metals is one of the most promising technologies involved in the removal of toxic metals from the industrial waste, streams and natural waters. The major advantages of the bioremoval technology are its effectiveness in reducing the concentration of heavy metal ions to very low levels and its use of inexpensive biosorption materials and environmentally friendly technologies. The idea that aquatic plants help in bioaccumulation of heavy metals were proposed by many researchers. Table 1 indicates the ability of aquatic macrophytes to absorb different trace elements and heavy metals from water which has been organized from many years.

Phytoremediation refers to the use of plants to clean up contaminated soil and water. The plant used in phytoremediation technique must have considerable capacity of metal absorption its accumulation and strength (Mudgal *et al.*, 2010; Abbas *et al.*, 2015). Thus, the review article mainly focused to identify suitable aquatic macrophyte to remediate particular metal from the environment.

Pollutant	Aquatic macrophyte used to bioremediate it	Summary of results	References
Pb	*Typha latifolia L.*, *Ceratophyllum demersum L.*	Both the macrophyte can exclude toxic levels of metals. Total chlorophyll content and nitrogen contents in *T. latifolia* and *C. demersum* were adversely affected from Pb^{2+} concentrations dose dependently at each pH. Toxicity of Pb^{2+} on both macrophyes was pH dependent. The plants were adversely affected by pH 5.0 or more than pH 9.0. However, the lowest toxic effect of Pb^{2+} was found at pH 7.0. According to the parts of *T. latifolia*, Pb^{2+} amounts were found in all tested pH levels and the metal concentrations in the following order: root>leaf. Pb^{2+} concentrations in plant tissues in relation to pH were generally found for *T. latifolia* in following order in the roots: 9.0> 7.0> 5.0; in the leaves: 7.0> 9.0> 5.0, and in whole *C. demersum* tissues: 7.0> 9.0> 5.0.	Saygideger et al., 2004
K, Ca, Ti, Fe, Cr, Mn, Cu, Zn and Sr	*Salvinia sp.*	Trace element concentrations in plants and pond water were obtained using Total Reflection X-ray Fluorescence (TXRF) techniques. Values for the elements (K, Ca, Ti, Fe, Cr, Mn, Cu, Zn and Sr) concentrations in plant dry weight have been obtained after deducting metal contents of control plants. For each trace element, the aquatic *Salvinia* sp. plant showed to possess different affinity for the incorporation of the metals in its biomass. Results suggested the use of aquatic macrophytes *Salvinia* sp. for metal abatement in diluted wastewater.	Espinoza-Quinones, F. R., Zacarkim, C. E. Palacio, S. M., Obreg on, C. L. Zenatti, D. C. Galante, R. M., Rossi, N., Rossi, F. L., Pereira, I. and Welter, R. A., 2005
Cd, Pb	*Lemna polyrrhiza L.*	The expositionof *Lemna polyrhhiza* to different concentrations of Cd and Pb results in an increase in growth, pigment content, proline, protein and sugar contentat lower concentration; at higher concentration their decrease was observed. Cd effect was more significant than that of Pb in hampering plant growth and development. Cd was accumulated more than Pb by *L. polyrrhiza*. Phytoremediation may contribute in the treatment of various sites sontaminated with heavy metals/ toxic metals. *L.polyrrhiza* can be used to reclaim the water bodies polluted with heavy metals.	John et al., 2008

Pollutant	**Aquatic macrophyte used to bioremediate it**	**Summary of results**	**References**
Cu, Cd, Zn, Ni,	*Lemna minor*	Aquatic macrophytes could survive in a medium containing elevated concentrations of Ni and Zn (3 mg Ni/l or 15mg Zn/l). Copper and Cadmium were considered as toxic for *L. minor*. At low concentration (0.5mg/L) the plants exhibited chlorosis and frond disconnection which progressed to necrosis (dead fronds). On the basis of visible symptoms and the EC50 values, the toxicity of the metals on *Lemna minor* was in decreasing order of damage: Cu > Cd > Ni > Zn. It was concluded that the duckweed *Lemna minor* is very sensitive to copper and cadmium pollution.	Khellaf, N. and Zerdaoui M., 2009
Cd	Salvnia	Salvinia can be recommended as a plant species with greater potential for use in phytoremediation of contaminants including heavy metals. Though protocols need to be developed and further studies are required to understand mechanisms involved in the uptake/ removal of contaminants so that maximum potential can be utilized for use in phytoremediation technology.	Dhir, B., 2009
Cu, Ni Fe	*Hydrilla verticillata, Elodea Canadensis, Salvinia* sp.	These species were grown at 5 mg/L concentrations of Fe, Cu and Ni in single metal solution. These plants have performed extremely well in removing the Fe, Cu, and Ni from their solution and were capable of removing up to 98% of Fe , 95% of Copper and 90 % of Nickel during 10 days dosimetry. Results indicated that at 5 mg/L of heavy metal concentration of Iron, the plant growth was normal and removal efficiency was greater. Removal of Iron for the period of ten days dosimetry was found harmless, without any symptom of toxicity in all the three plants. But in case of Copper and Nickel, all the plants have shown some morphological symptoms of toxicity after 5 days of dosimetry. And *Salvinia* sp., is capable in improving water quality to the maximum extent by reducing nutrient concentration.	Abida B., Harikrishna S., 2010
Cd and Pb	*Hyrocotyle ranocloides, Ceratophyllum demersum*	Results show an average concentration of lead in *Ceratophyllum* being 53.11 ppm, for Hydrocotyle 77.8 ppm, and of cadmium in *Ceratophyllum* being 4.46 ppm and for Hydrocotyle 6.28 ppm. According to results, lead has been the most abundant between these two metals inside plant organs regardless the specie. The statistic test gives the results under the confidence level 95% proving the amount of the absorption being significant in the stem of Hydrocotyle plant rather than in the root or the leaf compared with other species.	Vahdatiraad, L.; Khara, H., 2012

Pollutant	Aquatic macrophyte used to bioremediate it	Summary of results	References
Cr, Ni, Zn, Fe, Cu, Pb, Hg, Al, P, Cd	*Azolla filiculoides, Hydrilla verticillata, Lemna minor, Pistia stratoites, Salvinia natans, Spirodela polyrhhiza, Wolffia globosa*	Plant species have ability to remediate heavy metals are *Azolla filiculoides* - Cr,Ni,Zn Fe,Cu and Pb. *Hydrilla verticillata* - Hg,Fe,Ni, Pb *Lemna minor* – Mn, Pb,Ba,B,Cd,Cu,Cr,Ni,Se,Zn, Fe *Pistia stratoites* – Cu, Al, Cr, P, Hg *Salvinia natans* - Pb, Cr *Spirodela polyrhhiza* – Cr *Wolffia globosa* – Cd, Cr	Kasim S. A. and Rahman N. A, 2013
Fe, Cu, Cd, Zn, Ni, Pb	*Potamogeton pectinatus, Ceratophyllum demersum, Najas armata, Lemna gibba, Eichhornia crassipes*	*Eichhornia crassipes* showed high level of copper while in *Ceratophyllum demersum* high concentration of Iron was detected. Bioaccumulation factor values showed that the trend of accumulation of most metals was *Lemna gibba* > *Potamogeton pectinatus*> *Ceratophyllum demersum* > *Eichhornia crassipes* > *Najas armata* > *Phragmites australis* which make them suitable candidate to be used in biomonitoring survey as good tool for heavy metal pollution marker, in biological treatment of polluted water.	Ali., E.M., and Zyada, M.A., 2015
Lead	Ceratophyllum demersum and Eichhornia crassipes	*E. crassipes* is the best plant in phytoremediation of Pb from polluted water than *C.demersum* the plant ability to absorb Pb associated with the concentration in aqueous media as observed inability *C. demersum* plant to tolerate high concentration of Pb while *E. crassipes* has ability to absorb Pb even at high concentration. *E. crassipes* has been successfully used as the bio sorbent for removal of different concentrations of Pb.	Abbas A.S. and Al-Kubaisi, A.A., 2015

VI. Conclusion

In conclusion, these reviews indicate the potential of aquatic plants for removal of heavy metals from aquatic bodies with the advantage of low cost raw material. This review showed that aquatic plant such as *Pistia*, *Echhornia*, *Salvinia Hydrilla*, *Lemna* can have remedial try effects on heavy metal removal from wastewater.

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